Surface Sediment Sampling at Outfalls in the Lower Duwamish Waterway Seattle, WA

Data Report

Prepared for

DEPARTMENT OF ECOLOGY
State of Washington

Toxics Cleanup Program
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List of Acronyms

2LAET	second lowest apparent effects threshold
AET	apparent effects threshold
ARI	Analytical Resources, Inc.
Axys	Axys Analytical Services, Ltd.
BEHP	bis(2-ethylhexyl)phthalate
Boeing	The Boeing Company
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSL	Cleanup Screening Level
CSO	combined sewer overflow
DGPS	Differential Global Positioning System
DW	dry weight
Ecology	Washington State Department of Ecology
EPA	United States Environmental Protection Agency
GIS	Geographic Information Systems
GPS	Global Positioning System
HPAH	high molecular weight polycyclic aromatic hydrocarbons
HpCDD	heptachlorodibenzo-*p*-dioxin
HpCDF	heptachlorodibenzofuran
HxCDD	hexachlorodibenzo-*p*-dioxin
HxCDF	hexachlorodibenzofuran
ID	identification
LAET	lowest apparent effects threshold
LCS/LCSD	laboratory control sample/ laboratory control sample duplicate
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
LPAH	low molecular weight polycyclic aromatic hydrocarbons
MLLW	mean lower low water
MS/MSD	matrix spike/ matrix spike duplicate
MTCA	Model Toxics Control Act
OC	organic carbon
OCDD	octachlorodibenzo-*p*-dioxin
OCDF	octachlorodibenzofuran
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PeCDD	pentachlorodibenzo-*p*-dioxin
PeCDF	pentachlorodibenzofuran
PEF	potency equivalency factor
Port	the Port of Seattle
PSEP	Puget Sound Estuary Program
QA/QC	quality assurance/quality control
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RL	reporting limit
SAIC	Science Applications International Corporation

SAP/QAPP	Sampling and Analysis Plan/Quality Assurance Project Plan
SIM	selected ion monitoring
SMS	Washington State Sediment Management Standards
SQS	Sediment Quality Standard
SVOC	semi-volatile organic compounds
TCDD	tetrachlorodibenzo-*p*-dioxin
TCDF	tetrachlorodibenzofuran
TEF	toxic equivalency factor
TEQ	toxic equivalency
TOC	total organic carbon
WAC	Washington Administrative Code
WSDOT	Washington State Department of Transportation
WW	wet weight

1.0 Introduction

The Lower Duwamish Waterway (LDW) is located south of Elliott Bay in Seattle, Washington (Figure 1). The LDW site consists of 5.5 miles of the Duwamish Waterway as measured from the southern tip of Harbor Island to just south of the Norfolk Combined Sewer Overflow (CSO). The LDW has been identified as a Superfund site by the U.S. Environmental Protection Agency (EPA) and a Model Toxics Control Act (MTCA) site by the Washington State Department of Ecology (Ecology).

The key parties involved in the LDW site are EPA, Ecology, and the Lower Duwamish Waterway Group (LDWG), which is composed of representatives of the City of Seattle, King County, the Port of Seattle (the Port), and The Boeing Company (Boeing). In December 2000, EPA and Ecology signed an agreement with the LDWG to conduct a Remedial Investigation/ Feasibility Study (RI/FS) for the LDW site. As part of the RI/FS, the LDWG conducted extensive surface and subsurface sediment characterization sampling throughout the LDW (Windward 2010).

These and other previous sediment quality investigations have documented contaminants in surface and subsurface sediments at concentrations above the Washington State Sediment Management Standards (SMS) (Ecology 1995; Chapter 173-204, Washington Administrative Code [WAC]). Stormwater outfalls and CSOs have been identified as a potential source of contaminants to LDW sediments.

Ecology is the lead agency for source control for the LDW site. Source control is the process of finding and eliminating or reducing releases of contaminants to LDW sediments to the extent practicable. The goal of source control is preventing or minimizing the recontamination of sediments after cleanup has been completed.

As part of its source control responsibilities, Ecology tasked Science Applications International Corporation (SAIC) with updating an outfall inventory and conducting a sediment sampling study to provide a better understanding of the relationship between stormwater and combined sewer outfalls and surface sediment contamination in the LDW.

This data report describes the collection of surface sediment samples at 162 locations near 84 outfalls during March and April 2011 and presents the analytical sample results. In addition, this report includes a summary of deviations from the original Sampling and Analysis Plan/Quality Assurance Project Plan (SAP/QAPP) (SAIC 2011) and difficulties encountered during sample collection.

1.1 Study Objectives

The purpose of this study was to collect data to characterize the quality of LDW surface sediment near stormwater outfalls and CSOs in locations where data had not previously been collected.

As part of this study, SAIC compiled information about outfalls that discharge to the LDW, starting with the 243 outfalls listed in Appendix H of the LDW Remedial Investigation (RI) Report (Windward 2010). Appendix H of the RI Report includes limited information about the outfall locations, ownership, associated National Pollutant Discharge Elimination System permits, outfall size, and material of construction, but it does not include chemical data. SAIC has updated this outfall inventory, and expanded it to include available data from sampling of stormwater/CSOs and storm drain solids in the drainage systems associated with each outfall. SAIC also included available LDW surface sediment sampling data in close proximity (within 50 to 100 feet) to each outfall. This updated and expanded outfall inventory, including recommendations for future sampling, will be submitted to Ecology as part of a separate Technical Memorandum.

Based on preliminary updates to the outfall inventory, it became clear that no surface sediment data had been collected near many of these outfalls. Ecology determined that additional sampling was warranted in order to fill these data gaps and provide information needed to better understand the relationship between storm drain outfalls and sediment contamination. The objective of this sampling effort was to fill these data gaps. The chemical results of this sampling effort are presented in Section 3.0.

2.0 Field Sampling

This section summarizes the field sampling performed during this investigation. The methods for sample collection, processing, identification, and documentation are described in full detail in the *Surface Sediment Sampling at Outfalls in the Lower Duwamish Waterway, Seattle, WA; Sampling and Analysis Plan/Quality Assurance Project Plan* (SAIC 2011). Ecology, with assistance from SAIC, prepared a fact sheet and information letter that was mailed to local property owners and facility operators, describing the planned sampling objectives and activities. In addition, Ecology established or attempted to establish access agreements with property owners adjacent to the LDW, where required.

2.1 Surface Sediment Sampling

Field activities commenced with a reconnaissance of the LDW during a nighttime extreme low tide on January 31, 2011. The reconnaissance was used to identify areas of potential sampling difficulty. Surface sediment sample collection was conducted between February 28, 2011 and April 20, 2011. The *R/V Growler*, a research boat owned and operated by SAIC, was used to gain access to the planned sample collection areas within 50 feet of outfalls of 24-inch diameter or less, or within 100 feet of outfalls of greater than 24-inch diameter. Surface sediment (0 to 10 centimeters) samples were collected using either a 0.1 m^2 modified Young's grab sampler or a Petite Ponar grab sampler. Where sampling locations were not accessible by boat, near-shore surface sediment samples were collected by personnel on foot using a stainless steel spoon during low tide. Sampling procedures followed Puget Sound Estuary Program (PSEP) protocols (PSEP 1997a,b,c).

The coordinates of grab sample locations were measured with a global positioning system (GPS), differential global positioning system (DGPS), or using photographs and geographic information system (GIS) software. Sampling conditions were documented at the time of sample collection. Sample dates, times, sediment sample depths, water depths above or below mean lower low water (MLLW), and coordinates for all sampling locations are presented in Table 2–1. Sample collection locations are presented in Figure 2, and surface sediment sample collection log forms are provided in Appendix D.

Table 2–1. Surface Sediment Sampling Locations

Outfall ID	Location ID	Date	Time	X [a]	Y [a]	Sample Depth (cm)	Depth Above or Below (-) MLLW (ft)
2008	LDW-SS2008-A	03/08/11	14:28	1268272.99	205261.66	0 - 6	-12.9
2009	LDW-SS2009-A	03/08/11	13:34	1268347.65	204996.30	0 - 6	-10.0
	LDW-SS2009-U	03/08/11	13:50	1268367.32	204970.37	0 - 3	-8.0
2010	LDW-SS2010-A	03/21/11	13:35	1268509.95	204515.81	0 - 8.5	-8.6
	LDW-SS2010-D	03/21/11	13:24	1268509.35	204564.32	0 - 8.5	-8.4
	LDW-SS2010-U	03/21/11	13:53	1268522.79	204485.16	0 - 9.5	-8.1
2011	LDW-SS2011-A	03/21/11	14:21	1268594.19	204315.26	0 - 4	-1.2
	LDW-SS2011-D	03/21/11	14:10	1268577.28	204332.79	0 - 5	-3.1

Table 2–1. Surface Sediment Sampling Locations (continued)

Outfall ID	Location ID	Date	Time	X [a]	Y [a]	Sample Depth (cm)	Depth Above or Below (-) MLLW (ft)
2013	LDW-SS2013-A	04/08/11	13:43	1268682.80	204170.57	0 - 9	0.9
	LDW-SS2013-D	04/08/11	13:32	1268660.86	204204.58	0 - 9	1.8
	LDW-SS2013-U	04/08/11	13:57	1268718.23	204148.16	0 - 9	0.7
2015	LDW-SS2015-D	03/08/11	11:04	1268869.02	203428.25	0 - 5	-9.1
2018	LDW-SS2018-U	03/08/11	10:49	1269036.23	202968.33	0 - 4.5	-9.0
2019	LDW-SS2019-A	04/15/11	09:49	1269581.63	203349.03	0 - 7.5	-2.9
2021	LDW-SS2021-A	03/24/11	14:33	1269356.08	202733.76	0 - 9	1.2
	LDW-SS2021-D	03/24/11	14:48	1269341.81	202713.09	0 - 9	1.2
	LDW-SS2021-U	03/24/11	14:32	1269364.45	202750.99	0 - 9	1.2
2022	LDW-SS2022-A [b]	03/24/11	12:11	1269302.10	202034.67	0 - 7.5	-13.7
	LDW-SS2022-D	03/24/11	11:58	1269292.33	202053.23	0 - 8.5	-13.4
2025	LDW-SS2025-A [b]	04/15/11	08:40	1270812.00	201446.58	0 - 9	-7.2
2027	LDW-SS2027-A	03/24/11	09:51	1271278.06	200320.18	0 - 6.5	-3.0
2029	LDW-SS2029-A	04/15/11	10:43	1271090.44	200376.66	0 - 10	-4.6
	LDW-SS2029-D	04/15/11	10:31	1271059.11	200381.48	0 - 9.5	-4.7
2030	LDW-SS2030-A	04/15/11	10:53	1271125.57	200371.75	0 - 9	-4.7
	LDW-SS2030-U	04/15/11	11:06	1271189.73	200377.93	0 - 10	-4.1
2032	LDW-SS2032-A	04/15/11	11:23	1271135.74	200384.33	0 - 8	-3.8
2034	LDW-SS2034-D	03/24/11	10:20	1271354.47	199962.35	0 - 7.5	-9.0
	LDW-SS2034-U [b]	03/24/11	10:36	1271398.41	199930.02	0 - 9	-8.8
2035	LDW-SS2035-A	03/07/11	12:18	1271474.02	199752.87	0 - 10	-11.9
	LDW-SS2035-D	03/07/11	12:06	1271471.17	199775.42	0 - 10	-10.9
	LDW-SS2035-U	03/07/11	12:35	1271507.19	199743.11	0 - 8.5	-10.2
2036	LDW-SS2036-A	03/07/11	11:51	1271742.47	199475.86	0 - 10	-7.1
	LDW-SS2036-D	03/07/11	11:40	1271722.97	199510.90	0 - 9	-7.0
2037	LDW-SS2037-A	03/07/11	13:22	1271754.61	199464.68	0 - 9	-6.5
	LDW-SS2037-D	03/07/11	12:54	1271754.85	199477.44	0 - 8	-6.0
	LDW-SS2037-U	03/07/11	13:40	1271793.57	199456.53	0 - 6.5	-2.6
2038	LDW-SS2038-A	03/03/11	12:04	1271840.15	199395.53	0 - 6	-1.5
	LDW-SS2038-D	03/03/11	12:20	1271829.22	199405.47	0 - 6	-1.5
2039	LDW-SS2039-A	03/03/11	11:05	1271827.42	199376.31	0 - 9.5	-3.0
	LDW-SS2039-D	03/03/11	10:35	1271832.88	199402.96	0 - 10	-4.8
2040	LDW-SS2040-A	03/04/11	14:37	1272018.15	199210.27	0 - 5	2.6
	LDW-SS2040-D	03/04/11	14:21	1271994.89	199221.05	0 - 5	3.2
	LDW-SS2040-U	03/04/11	14:57	1272043.44	199176.94	0 - 3.5	2.6
2078	LDW-SS2078-A	03/21/11	16:57	1277325.44	192986.34	0 - 7	-2.1
	LDW-SS2078-D	03/21/11	17:09	1277281.94	192968.32	0 - 9	0.7
	LDW-SS2078-U	03/21/11	16:46	1277346.63	192994.77	0 - 10	-0.1
2080	LDW-SS2080-A	03/21/11	16:31	1277430.65	193028.48	0 - 8	-2.0
2082	LDW-SS2082-U [c]	03/17/11	09:22	1277071.60	192633.99	0 - 10	-4.1
2083	LDW-SS2083-A [c]	03/17/11	09:47	1277027.46	192615.55	0 - 10	-3.6
2085	LDW-SS2085-A [c]	03/17/11	10:53	1276949.58	191329.81	0 - 8	1.8

Table 2–1. Surface Sediment Sampling Locations (continued)

Outfall ID	Location ID	Date	Time	X [a]	Y [a]	Sample Depth (cm)	Depth Above or Below (-) MLLW (ft)
2089	LDW-SS2089-A [c]	03/17/11	10:38	1276917.48	191869.74	0 - 10	-0.9
	LDW-SS2089-D [c]	03/17/11	10:19	1276901.34	191905.67	0 - 10	-0.9
2090	LDW-SS2090-A [c]	03/17/11	11:26	1277137.02	190855.16	0 - 8	1.2
	LDW-SS2090-D [c]	03/17/11	11:11	1277119.18	190882.69	0 - 7	2.7
2091	LDW-SS2091-U [c]	03/17/11	14:49	1277930.13	190472.54	0 - 5	-8.6
2092	LDW-SS2092-A [c]	03/18/11	08:47	1278207.65	190418.81	0 - 7	-0.6
2093	LDW-SS2093-D [c]	03/18/11	10:36	1278489.58	190251.19	0 - 6	0.0
2094	LDW-SS2094-D [c]	03/18/11	09:35	1278286.85	190362.31	0 - 8	-7.2
2096	LDW-SS2096-A [c]	03/18/11	12:02	1278420.78	190310.37	0 - 9	6.1
	LDW-SS2096-U [c]	03/18/11	12:02	1278450.50	190287.39	0 - 9.3	6.1
2097	LDW-SS2097-A [c]	03/18/11	09:18	1278249.02	190392.85	0 - 5.5	-2.1
	LDW-SS2097-D [c]	03/18/11	09:03	1278231.00	190402.39	0 - 7.5	-1.8
2098	LDW-SS2098-A	03/04/11	10:14	1276617.51	191090.51	0 - 10	-8.5
	LDW-SS2098-D	03/04/11	09:50	1276594.98	191118.30	0 - 9	-6.4
	LDW-SS2098-U	03/04/11	10:29	1276621.96	191043.00	0 – 10	-8.8
2099	LDW-SS2099-A	03/03/11	16:08	1276578.65	191255.43	0 - 10	-7.3
	LDW-SS2099-D	03/03/11	15:48	1276547.56	191288.25	0 - 9	1.2
	LDW-SS2099-U	03/03/11	16:26	1276589.86	191260.08	0 - 10	-6.7
2103 (SP 4) [d]	LDW-SS2103-A	03/04/11	11:40	1275746.04	194902.07	0 - 3	0.9
	LDW-SS2103-D	03/04/11	11:27	1275753.11	194927.47	0 - 3.5	-0.2
	LDW-SS2103-U	03/04/11	12:25	1275751.89	194863.65	0 - 9	4.4
2106	LDW-SS2106-A	03/04/11	13:25	1272585.58	198168.01	0 - 10	-5.1
	LDW-SS2106-D	03/04/11	13:02	1272554.37	198260.95	0 - 10	-8.8
	LDW-SS2106-U	03/07/11	09:48	1272579.78	198166.30	0 - 9.5	-2.0
2108	LDW-SS2108-A	03/07/11	10:03	1272572.79	198167.05	0 - 7	-1.9
	LDW-SS2108-U	03/07/11	10:13	1272594.95	198141.69	0 - 10	-1.7
2112	LDW-SS2112-A	04/08/11	12:14	1271964.73	198604.28	0 - 9.5	0.4
2113	LDW-SS2113-A [b]	03/07/11	08:58	1271745.52	198911.52	0 - 6.5	-1.1
	LDW-SS2113-U	03/07/11	09:28	1271754.87	198883.98	0 - 3	-1.0
2115	LDW-SS2115-A	04/15/11	12:41	1270771.59	199889.66	0 - 3.5	-0.2
	LDW-SS2115-D	04/15/11	12:22	1270764.30	199907.63	0 - 4	-0.7
	LDW-SS2115-U	04/15/11	12:54	1270793.71	199870.27	0 - 4	-0.7
2122	LDW-SS2122-A	03/08/11	08:48	1269089.09	201796.79	0 - 6.5	-13.5
	LDW-SS2122-D	03/08/11	09:24	1269048.65	201813.39	0 - 8	-6.2
	LDW-SS2122-U	03/08/11	09:39	1269071.54	201762.47	0 - 8.5	-6.7
2139	LDW-SS2139-A	04/08/11	10:46	1266715.37	206215.57	0 - 6	-5.2
2144	LDW-SS2144-A	03/14/11	16:27	1266193.39	209836.00	0 - 9.5	-5.7
2146	LDW-SS2146-A	03/14/11	16:08	1266198.85	209877.23	0 - 7	-3.0
2147	LDW-SS2147-D	03/14/11	15:41	1266175.40	209924.59	0 - 6	-4.4
2148	LDW-SS2148-A [b]	04/20/11	08:45	1265444.23	210880.09	0 - 9	8.0
2149	LDW-SS2149-A	04/20/11	08:15	1265167.34	210891.91	0 - 9	9.1
2150	LDW-SS2150-A	04/20/11	09:03	1265702.93	210848.09	0 - 9	7.2

Table 2–1. Surface Sediment Sampling Locations (continued)

Outfall ID	Location ID	Date	Time	X [a]	Y [a]	Sample Depth (cm)	Depth Above or Below (-) MLLW (ft)
2157	LDW-SS2157-A	03/24/11	17:04	1266368.36	209505.61	0 - 7	-37.8
2200	LDW-SS2200-A	03/18/11	12:58	1276619.66	190686.14	0 - 8.5	3.9
	LDW-SS2200-D	03/18/11	12:47	1276583.80	190762.76	0 - 6	0.3
2201	LDW-SS2201-A	03/18/11	13:22	1276642.31	190534.88	0 - 8.5	3.5
	LDW-SS2201-D	03/18/11	13:11	1276576.36	190583.50	0 - 7	4.7
	LDW-SS2201-U	03/18/11	13:33	1276661.87	190463.83	0 - 6.5	2.7
2214	LDW-SS2214-A	03/07/11	10:45	1275093.19	195842.49	0 - 10	-3.5
	LDW-SS2214-D	03/07/11	10:57	1275080.13	195848.82	0 - 10	-1.6
	LDW-SS2214-U	03/07/11	11:08	1275133.51	195819.22	0 - 8	-3.1
2223	LDW-SS2223-A	03/21/11	12:55	1268117.96	205958.88	0 - 4	-5.5
2232	LDW-SS2232-A	04/20/11	10:28	1265985.49	210263.86	0 - 9	5.6
	LDW-SS2232-D	04/20/11	10:06	1265966.82	210284.37	0 - 9	6.7
	LDW-SS2232-U	04/20/11	10:54	1265985.17	210241.36	0 - 9	4.3
2233	LDW-SS2233-D	04/20/11	09:50	1266001.28	210675.52	0 - 9	5.7
	LDW-SS2233-U	04/20/11	09:16	1265951.41	210554.84	0 - 9	7.4
2244	LDW-SS2244-A	03/21/11	12:29	1268037.31	206018.12	0 - 5.5	-18.8
	LDW-SS2244-D	03/21/11	12:13	1268012.27	206045.60	0 - 6.5	-14.8
2246	LDW-SS2246-A	03/21/11	10:39	1267667.05	206971.00	0 - 4.5	-16.2
	LDW-SS2246-U [b]	03/21/11	11:09	1267682.77	206953.62	0 - 5	-16.1
2247	LDW-SS2247-A	03/21/11	11:38	1267740.93	206845.18	0 - 8.5	-26.5
	LDW-SS2247-U	03/21/11	11:52	1267763.92	206832.94	0 - 6.5	-27.9
2503	LDW-SS2503-A	03/24/11	11:48	1269641.64	201823.92	0 - 10	6.5
2505	LDW-SS2505-A	03/07/11	14:14	1269552.83	201106.63	0 - 9	3.6
2506	LDW-SS2506-A	03/07/11	15:18	1269556.96	201171.69	0 - 6	-2.8
	LDW-SS2506-D	03/07/11	15:06	1269533.67	201223.22	0 - 7	-5.1
2512	LDW-SS2512-A	03/07/11	14:29	1269595.16	201037.65	0 - 9	4.5
	LDW-SS2512-U	03/07/11	14:36	1269612.87	200990.84	0 - 9	4.7
3037	LDW-SS3037-A	03/03/11	13:54	1274034.63	196883.18	0 - 5	-0.8
	LDW-SS3037-D [b]	03/03/11	13:25	1274000.66	196894.17	0 - 8.5	-0.6
	LDW-SS3037-U	03/03/11	14:18	1274062.71	196866.22	0 - 6	-1.3
5000	LDW-SS5000-A	04/08/11	14:24	1268126.61	206823.75	0 - 8.5	-26.4
	LDW-SS5000-D	04/08/11	14:10	1268093.77	206808.88	0 - 8.5	-26.3
	LDW-SS5000-U	04/08/11	14:36	1268164.91	206813.40	0 - 8.5	-27.0
5002	LDW-SS5002-A	03/24/11	15:48	1267891.98	205186.43	0 - 5	-31.6
	LDW-SS5002-D	03/24/11	16:04	1267831.56	205245.35	0 - 5	-27.4
5003	LDW-SS5003-A	03/24/11	16:40	1267891.04	205185.98	0 - 5	-29.8
5005	LDW-SS5005-A	03/24/11	16:17	1267859.56	205139.55	0 - 5	-22.6
6146	LDW-SS6146-A	03/21/11	14:44	1268494.16	203166.52	0 - 8.5	-25.6
	LDW-SS6146-D	03/08/11	10:01	1268477.85	203214.57	0 - 10	-27.0
	LDW-SS6146-U	03/21/11	14:57	1268483.74	203136.27	0 - 9.5	-24.2

Table 2–1. Surface Sediment Sampling Locations (continued)

Outfall ID	Location ID	Date	Time	X [a]	Y [a]	Sample Depth (cm)	Depth Above or Below (-) MLLW (ft)
BDC-2	LDW-SSBDC2-A [b,c]	03/17/11	12:33	1277437.40	190557.39	0 - 7	-1.1
	LDW-SSBDC2-D [c]	03/17/11	12:16	1277416.70	190574.47	0 - 6	0.3
	LDW-SSBDC2-U [c]	03/17/11	12:51	1277473.44	190546.10	0 - 5	0.0
BDC-3	LDW-SSBDC3-D [c]	03/17/11	13:14	1277539.09	190536.94	0 - 6	1.9
	LDW-SSBDC3-U [c]	03/17/11	13:43	1277621.44	190515.64	0 - 6	0.3
BDC-4	LDW-SSBDC4-A [c]	03/17/11	14:18	1277653.02	190518.83	0 - 7	-1.0
S Brighton St SD	LDW-SSBRSTSD-A	03/04/11	15:46	1270298.65	201074.53	0 - 9	-13.6
	LDW-SSBRSTSD-D	03/04/11	15:30	1270277.68	201096.83	0 - 10	-13.9
	LDW-SSBRSTSD-U	03/04/11	16:03	1270315.24	201059.62	0 - 9.5	-13.7
Port - SF	LDW-SSPSF-A	03/07/11	15:57	1269181.69	201689.78	0 - 4	-14.4
	LDW-SSPSF-D	03/07/11	15:46	1269164.75	201707.75	0 - 6.5	-14.8
	LDW-SSPSF-U [b]	03/07/11	16:46	1269190.73	201667.72	0 - 6.5	-13.2
S River Street SD	LDW-SSRVSTSD-A	03/04/11	16:40	1269787.67	201600.64	0 - 4.5	-9.5
	LDW-SSRVSTSD-D	03/04/11	16:23	1269764.94	201603.21	0 - 6.5	-9.7
EE7	LDW-SSRWSD-A [b]	03/18/11	11:32	1279921.32	188902.59	0 - 10	-6.7
Ryan Way SD	LDW-SSRWSD-Ab	04/08/11	11:46	1279680.36	189425.11	0 - 6	-6.0
SP 1	LDW-SSSP1-A	03/24/11	13:48	1275891.39	194090.20	0 - 10	0.4
	LDW-SSSP1-D	03/24/11	13:47	1275884.92	194131.95	0 - 9	0.4
	LDW-SSSP1-U	03/24/11	13:57	1275890.22	194056.68	0 - 9	0.6
SP 2	LDW-SSSP2-A	03/24/11	13:22	1275845.09	194282.17	0 - 9	1.3
	LDW-SSSP2-D	03/24/11	13:21	1275841.57	194308.64	0 - 9	1.3
	LDW-SSSP2-U	03/24/11	13:32	1275855.68	194254.54	0 - 9	1.1
SP 3	LDW-SSSP3-A	03/24/11	12:53	1275807.12	194504.90	0 - 9	1.8
	LDW-SSSP3-D	03/24/11	12:52	1275803.00	194533.71	0 - 9	1.8
	LDW-SSSP3-U	03/24/11	13:06	1275811.82	194481.37	0 - 9	1.3
SP 5	LDW-SSSP5-A	03/03/11	14:50	1275664.38	195154.15	0 - 3.5	0.9
Siphon-West CSO	LDW-SSSWCSO-A	04/08/11	09:35	1266476.86	209115.22	0 - 5	-35.2
	LDW-SSSWCSO-U	04/08/11	10:15	1266401.55	209073.53	0 - 5	-14.1
Boyer - Unknown	LDW-SSUNK-A	04/15/11	12:01	1270751.99	199927.61	0 - 6.5	-0.8
	LDW-SSUNK-D	04/15/11	11:47	1270730.48	199950.00	0 - 9.5	1.1

ID = identification; MLLW = mean lower low water

a. coordinates are reported in North American Datum 1983 (NAD83) horizontal datum, Washington, State Plane North (feet).

b. A field duplicate sample was collected at this location.

c. Split samples were collected at this location and delivered by SAIC to Analytical Resources, Inc. on behalf of Boeing/Calibre. These samples are identified with a suffix "-BS" to indicate "Boeing Split."

d. Outfall 2103 is the same outfall also identified as SP 4.

2.2 Sample Identification

Sediment samples were identified by the project area "LDW-," "SS" to indicate surface sediment, the nearby outfall number or abbreviated name, and additional suffix ("-A" for adjacent, "-U" for upstream, "-D" for downstream, and/or "-2" for field duplicate samples), as applicable. The outfall attributed to any given sample ID was assigned based on the outfall closest to the target sampling location.

For example:

LDW-SS2223-U is the surface sediment sample collected upstream from outfall number 2223 in the LDW.

LDW-SSHRE1-A-2 is the field duplicate surface sediment sample collected adjacent to the outfall named "HRE1"in the LDW.

2.3 Field Deviations to the Sampling and Analysis Plan

As described in the project SAP/QAPP (SAIC 2011), 246 surface sediment grab samples were planned for collection near 114 outfalls. However, modifications to the sampling design were anticipated during field operations depending on actual site conditions observed during sampling or because of other restrictions (e.g., lack of accessibility). Surface sediment samples were successfully collected at 162 sampling locations near 84 outfalls (Figure 2).

Ninety surface sediment samples planned for collection near 51 outfalls were not collected because actual site conditions or other restrictions prevented successful sample collection, or because sampling locations were consolidated due to overlap. Six additional surface sediment samples that were not planned for collection in the SAP/QAPP were collected near outfalls identified during field sampling activities or because nearby planned samples could not be collected because of obstructions. The actual number of outfalls represented by sample collection may vary because of overlapping proximity goals.

Samples that were not collected as planned in the project SAP/QAPP are listed in Table 2–2, with recommendations for future sampling, if applicable. The most common reasons for these field sampling deviations are summarized and further defined as follows:

Riprap/rocky substrate: Representative surface sediment samples could not be effectively collected with standard sampling equipment because gravel or cobbles would not allow the grab samplers to fully close. Consequently, any sediment that was collected was disturbed and/or lost completely as the sampler was retrieved. Several attempts were made to successfully collect samples at planned locations, as documented in the field sampling logs and notes presented in Appendix D.

Obstructions: Surface sediment samples could not be collected due to structural hindrances that prevented access to the target sample collection area, such as docks, bulkheads, barges docked in front of the outfall, pilings, cables, or catwalks.

Property access not permitted: Surface sediment samples could not be collected where property access was not permitted due to legal requirements.

A field decision was made to consolidate sampling locations because of proximity to other sampling locations: Several surface sediment sampling areas were anticipated to overlap in spatial coverage between outfalls. It was determined in the field that additional sampling location consolidation was reasonable to simplify field activities and minimize overlap.

Table 2–2. Summary of Planned Sediment Samples that were Not Collected and Recommendations for Future Sediment Sampling

Outfall ID	Sampling Position Planned for Collection [a]	Reason Samples Were Not Collected	Recommendations for Future Sediment Sampling
2003	A, D, U	riprap/rocky substrate	Possible sampling on foot during daytime low-low tide.
2004	A, D, U	obstructions (dock)	None. This outfall is not accessible due to its location under the dock and behind pilings.
2005	A, D, U	riprap/rocky substrate	None. Riprap near the outfall hinders sediment sampling. The upstream sample was also intended to provide overlapping coverage for the downstream position at outfall 2246.
2006	A, D, U	riprap/rocky substrate	None. Riprap near the outfall hinders sediment sampling.
2007	D	riprap/rocky substrate	Possible sampling on foot during daytime low-low tide.
2008	D, U	riprap/rocky substrate	None. Riprap near the outfall hinders sediment sampling.
2009	D	riprap/rocky substrate	Possible sampling on foot during daytime low-low tide.
2011	U	riprap/rocky substrate	Possible sampling on foot during daytime low-low tide.
2014	A, D, U	riprap/rocky substrate	None. Riprap near the outfall hinders sediment sampling.
2015	A	riprap/rocky substrate	None. Riprap near the outfall hinders sediment sampling.
2017	A, D, U	riprap/rocky substrate	None. Riprap near the outfall hinders sediment sampling.
2018	D	riprap/rocky substrate	None. Riprap near the outfall hinders sediment sampling.
2022	U	obstructions (tugs/barges and cables)	None. Outfall is located on a steep shore, behind pilings, with constant tug/barge traffic adjacent to the shore.
2030	D	location overlaps with LDW-SS2029-A	None.
2039	U	location overlaps with LDW-SS2038-A	None.
2083	D	obstructions (bulkhead)	None. *Note*: these are hydraulic pressure relief pipes that drain infiltrated tidal waters from behind the bulkhead. They are therefore part of the original bulkhead design rather than "outfalls."
2094	A	riprap/rocky substrate	Possible sampling on foot during daytime low-low tide. Since the waterway is more shallow this far upstream, a boat may not be able to access it. This would likely require upland access permitted by Boeing.
2109	A, D, U	obstructions (barges continuously docked in front of outfall)	Possible sampling on foot during daytime low-low tide, via upland access permitted by the adjacent property owner.
2110	A	obstructions (outfall located behind dock, crane, and catwalk)	Possible sampling on foot during daytime low-low tide, via upland access permitted by the adjacent property owner.

Table 2–2. Summary of Planned Sediment Samples that were Not Collected and Recommendations for Future Sediment Sampling (continued)

Outfall ID	Sampling Position Planned for Collection [a]	Reason Samples Were Not Collected	Recommendations for Future Sediment Sampling
2111	A, D	obstructions (outfall located behind dock, crane, and catwalk)	Possible sampling on foot during daytime low-low tide, via upland access permitted by the adjacent property owner.
2113	D	obstructions (a dock and catwalk on either side)	Possible sampling on foot during daytime low-low tide, via upland access permitted by the adjacent property.
2114	A, D	obstructions (barges continuously docked in front of outfall)	Possible sampling on foot during daytime low-low tide, via upland access permitted by the Boyer Towing property owner.
2116	A, D, U	riprap/rocky substrate	Possible sampling on foot during daytime low-low tide, via upland access permitted by the Boyer Towing property owner.
2136	A, U	locations eliminated because outfall is no longer in operation	None. This outfall was confirmed by Ecology to be decommissioned.
2137	A	location overlaps with LDW-SS5005-A	None.
2138	A, D, U	obstructions (barges continuously docked in front of outfall with cables blocking access)	Possible sample collection from research vessel only while barges/tugs are not docked in front of outfall.
2140	A	property access was unavailable	Possible sample collection if access can be obtained from Seattle City Parks Department.
2141	A	property access was unavailable	Possible sample collection if access can be obtained from Seattle City Parks Department.
2142	A	property access was unavailable	Possible sample collection if access can be obtained from Seattle City Parks Department.
2143	A	property access was unavailable	Possible sample collection if access can be obtained from Seattle City Parks Department.
2144	U	riprap/rocky substrate	Possible sample collection on foot closer to the outfall during daytime low-low tide. This sample was also intended to provide overlapping coverage for the upstream position at outfall 2145.
2145	A	location overlaps with LDW-SS2144-A	None.
2146	D	location overlaps with LDW-SS2147-D	None.
2151	A	riprap/rocky substrate	None. Riprap near the outfall hinders sediment sampling.
2154	A, D, U	riprap/rocky substrate	None. Riprap near the outfall hinders sediment sampling.
2156	A, D, U	riprap/rocky substrate	None. Riprap near the outfall hinders sediment sampling.
2157	D, U	obstructions (dock extending over and beyond the outfall)	None. The sample collected adjacent to this outfall is considered to be the most representative sample that can feasibly be collected.

Table 2–2. Summary of Planned Sediment Samples that were Not Collected and Recommendations for Future Sediment Sampling (continued)

Outfall ID	Sampling Position Planned for Collection [a]	Reason Samples Were Not Collected	Recommendations for Future Sediment Sampling
2220	A, D, U	obstructions (bulkhead) for –D and –A locations; riprap/rocky substrate for the –U location.	None. Riprap near the outfall hinders sediment sampling.
2223	D, U	riprap/rocky substrate for the –D location; obstructions (pilings, rocks) for –U location	Possible sampling on foot during daytime low-low tide.
2226	A, U	property access was unavailable	Possible sample collection if access can be obtained from Seattle City Parks Department.
2501	U [b]	proximity to a cable crossing the waterway	None. Collection of representative samples near this outfall is not considered feasible.
2502	D [b]	proximity to a cable crossing the waterway	None. Collection of representative samples near this outfall is not considered feasible.
5004	D, U [b]	downstream location overlaps with LDW-SS5003-A; upstream location overlaps with LDW-SS5005-A	None.
2100 (B)	A	property access was unavailable	Possible sample collection with access permitted by adjacent property owner.
BDC-4	D, U	downstream location overlaps with LDW-SSBDC3-U; riprap/rocky substrate at upstream location	None. The samples collected are considered the most feasible representative samples and no more sampling is considered necessary.
HRE 1	A, D, U	riprap/rocky substrate	None. Riprap near the outfall hinders sediment sampling.
SP 5	D, U	riprap/rocky substrate	Possible sampling on foot during daytime low-low tide.
SP 4 (2103)	A, D, U	outfall identified as both SP 4 and 2103	None. See samples LDW-SS2103-A, LDW-SS2103-D, and LDW-SS2103-U.
Nevada SD	A, D, U	riprap/rocky substrate	None. Riprap near the outfall hinders sediment sampling.
S River Street SD	U	riprap/rocky substrate	None. Riprap near the outfall hinders sediment sampling.

A = adjacent to outfall; D = downstream from outfall; ID = identification; U = upstream from outfall

a. Samples planned for collection within 50 feet of the outfall unless otherwise noted.

b. Sample planned for collection within 100 feet of the outfall.

Several surface sediment samples could not be collected within the established location criteria (within 50 feet of outfalls 24-inches in diameter or less, or within 100 feet of outfalls greater than 24 inches in diameter) because of riprap/rocky substrate, accessibility, or physical obstructions. When such difficulties were encountered, sampling locations were moved to the nearest possible location that did not significantly exceed the proximity goals to the related outfall, as identified in Table 2–3.

Table 2–3. Samples Collected Outside of Outfall Proximity Goals

Outfall No.	Sampling Position	Distance from Outfall (ft)	Proximity Goal (ft)	Reason	Recommendations for Future Sediment Sampling
2010	D	60	50	riprap/rocky substrate	None.
2011	D	62	50	riprap/rocky substrate	Possible sample collection on foot closer to the outfall during daytime low-low tide.
2013	A	55	50	riprap/rocky substrate	None. Samples collected were collected on foot as close to the outfall as possible.
	D	68	50		
2022	D	57	50	obstructions (tugs/barges, cables)	None. Outfall is located on a steep shore, behind pilings, with constant tug/barge traffic adjacent to the shore.
2030	U	64	50	riprap/rocky substrate	None.
2032	A	60	50	riprap/rocky substrate, outfall located upland	None. This outfall is located upland.
2037	D	56	50	GPS inaccuracy	None.
2038	A	55	50	GPS inaccuracy	None.
2040	U	56	50	GPS inaccuracy	None.
2091	U	105	100	obstructions (pilings)	None.
2092	U	53	50	difficulty positioning boat	None.
2099	U	53	50	GPS inaccuracy	None.
2106	A	75 *(upstream)*	50	GPS inaccuracy and difficulty positioning the boat	Possible sample collection on foot closer to the outfall during daytime low-low tide.
	D	77	50		
2115	A	61	50	riprap/rocky substrate and property accessibility	Possible sample collection on foot during daytime low-low tide, via upland access permitted by the Boyer Towing property.
	D	70	50		
	U	68	50		
2122	A	55	50	obstruction (catwalk)	None.
2137	A, as overlapping sample LDW-SS5005-A	98	50	riprap/rocky substrate	None.
2038	A	55	50	GPS inaccuracy	None.
2144	D	71	50	riprap/rocky substrate	Possible sample collection on foot closer to the outfall during daytime low-low tide.
	A	67	50		

Table 2–3. Samples Collected Outside of Outfall Proximity Goals (continued)

Outfall No.	Sampling Position	Distance from Outfall (ft)	Proximity Goal (ft)	Reason	Recommendations for Future Sediment Sampling
2146	A	72	50	riprap/rocky substrate	Possible sample collection on foot closer to the outfall during daytime low-low tide. This sample also provides overlapping coverage for the downstream position at outfall 2144 (71 feet).
2157	A	93	50	obstructions (dock extending over and beyond the outfall)	None.
2201	D	102	100	property access not permitted	Possible sample collection from research vessel/on foot closer to the outfall with access permitted by the Muckleshoot Tribe.
	A	115	100		
	U	128	100		
2223	A	63	50	riprap/rocky substrate	Possible sample collection on foot closer to the outfall during daytime low-low tide.
3037	D	73	50	riprap/rocky substrate and the inaccuracy of GPS	Possible sample collection on foot closer to the outfall during daytime low-low tide.
	A	64 *(downstream)*	50		
	U	65 *(downstream)*	50		
Port - SF	D	56	50	obstructions (bulkhead)	None.
S Brighton Street SD	D	57	50	obstructions (overhead dock extending beyond the outfall)	None.
	A	52	50		
	U	56	50		
SP 5	A	57 *(downstream)*	50	riprap/rocky substrate and GPS inaccuracy	Possible sample collection on foot closer to the outfall during daytime low-low tide.
2103 (SP-4)	D	59	50	GPS inaccuracy	None.
	U	60	50	GPS inaccuracy	None.
2503	A	135	100	outfall located at head of 100-foot drainage ditch	None. The sample was collected at point of discharge into waterway.
2505	U	78	50	lack of DGPS while collecting on foot	None.
	D	83	50	lack of DGPS while collecting on foot	None.

A = adjacent to outfall; D = downstream from outfall; GPS = global positioning system; U = upstream from outfall

Some additional surface sediment samples were collected and/or analyzed for additional chemicals that were not planned in the project SAP/QAPP. The added samples and the rationale for their sampling and analysis are listed in Table 2–4. All field decisions represented in this table were made in consultation with Ecology.

Table 2–4. Additional Sediment Samples Collected and/or Analyzed

Outfall No.	Sample ID	SAP/QAPP Deviation and Reason for Deviation
2083	LDW-SS2083-A	This sample was collected and analyzed for SMS chemicals instead of the downstream location of 2083, which could not be collected due to obstructions (bulkhead).
2103 (SP-4)	LDW-SS2103-U	This sample was collected and analyzed for SMS chemicals. During field sampling, it was determined that SP-4 and 2103 were the same outfall. Samples adjacent to, downstream, and upstream of this outfall were identified as LDW-SS2103-A, LDW-SS2103-D, and LDW-SS2103-U, respectively.
5003	LDW-SS5003-A	This sample was collected and analyzed for SMS chemicals in place of the sample adjacent to outfall 5004, which could not be collected due to rocky substrate.
SP 3	LDW-SSSP3-D	The downstream sample was tested for dioxins/furans to obtain better coverage of the area, in place of other dioxin/furan samples not collected for various reasons.
Boyer - New	LDW-SSUNK-A, LDW-SSUNK-D	This outfall was discovered during field activities. A decision was made to collect downstream and adjacent samples; the upstream position was not sampled because it overlaps with sample LDW-SS2115-D. Sample LDW-SSUNK-D was analyzed for dioxins/furans.
EE7	LDW-SSRWSD-A	Unknown pipes at river mile 5.3 east were misidentified as the Ryan Way outfall during field sampling. Additional outfalls were observed nearby, one of which (at river mile 5.2 east) was later identified as the actual Ryan Way WSDOT outfall. A sample was collected at the correctly identified outfall as listed below.
Ryan Way SD	LDW-SSRWSD-Ab	See above.

SAP/QAPP = Sampling and Analysis Plan/Quality Assurance Project Plan; SMS = Washington State Sediment Management Standards; WSDOT = Washington State Department of Transportation

The SAP/QAPP specified the use of DGPS for determining the coordinates of sampling locations. Technical problems arose during field activities that compromised the functionality of DGPS. Additionally, the DGPS was not effective in select areas of the LDW because of obstructions to satellite reception at the location caused by nearby bridges or barges. Consequently, a non-differential GPS was used where DGPS was unavailable. Additionally, the coordinates of a few locations were estimated relative to a location fixed from the boat, the outfall, and/or photos taken at the time of sampling using GIS. The method used to determine sampling coordinates for each sampling location is recorded in the project database.

The SAP/QAPP notes that a rinse blank sample will be collected during every week of sample collection. A total of five rinse blank samples were collected during the investigation. Only dedicated, decontaminated equipment was used on the last day of sampling, April 20, 2011. Since there was no potential for cross contamination between samples, another rinse blank sample to cover this week was not collected.

3.0 Chemical Analysis

This section summarizes the test methods and analytical results for surface sediment samples collected in the LDW. The complete set of analytical results is presented in data tables in Appendix A, and original laboratory reports are provided in Appendix C. The data validation is summarized in Section 4.0 and the full validation report is presented in Appendix B.

3.1 Analytical Methods

All surface sediment samples were analyzed by Analytical Resources, Inc. (ARI) for metals, polychlorinated biphenyls (PCBs), semi-volatile organic compounds (SVOCs) including polycyclic aromatic hydrocarbons (PAHs) and phthalates, selected SVOCs by selected ion monitoring (SIM), total organic carbon (TOC), total solids, and grain size. A subset of samples was analyzed by Axys Analytical Services, Ltd. (Axys) for dioxin/furan congeners. The analytical methods are listed in Table 3–1. Additional details regarding analytical quality assurance/quality control (QA/QC) requirements are presented in the project SAP/QAPP (SAIC 2011). Sample analyses conformed to standard, EPA and PSEP (1997a,b,c) guidance and the project SAP/QAPP (SAIC 2011).

Table 3–1. Analytical Methods and Laboratory Name

Analyte Group	Analytical Method	Laboratory Name
Dioxins/Furans	EPA 1613B	Axys
PCB Aroclors	EPA 8082	ARI
SVOCs (including phthalates and PAHs)	EPA 8270D	ARI
Selected SVOCs by SIM	EPA 8270D-SIM	ARI
Mercury	EPA 6010B/200.8	ARI
Other metals	EPA 7471A	ARI
TOC	Plumb (1981)	ARI
Total solids	EPA 160.3	ARI
Grain Size	PSEP (1986)	ARI

ARI = Analytical Resources, Inc.; Axys = Axys Analytical Services, Ltd.; EPA = U.S. Environmental Protection Agency; PAHs = polycyclic aromatic hydrocarbons; PCBs = polychlorinated biphenyls; PSEP = Puget Sound Estuary Program; SIM = selected ion monitoring; SVOCs = semi-volatile organic compounds; TOC = total organic carbon

3.2 Results

This section summarizes results of the chemical analysis of surface sediment samples collected from 162 sampling locations. The results presented in this section and on associated figures represent original samples only; the results of field duplicate samples are presented in the data tables in Appendix A and are discussed in the data validation report in Appendix B.

Results were compared to SMS criteria for all chemicals with SMS criteria, and to natural background concentrations for the four LDW risk driver chemicals (arsenic, carcinogenic polycyclic aromatic hydrocarbons [cPAHs], total PCBs, and dioxins/furans), as applicable. Figure 3 presents all detected chemicals with concentrations that exceed SMS criteria. Sample concentrations for cPAHs and dioxins/furans, which do not have associated SMS criteria, are also presented in Figure 3. Where SMS criteria are expressed on an organic carbon (OC)-normalized basis, sediment results are also presented in OC-normalized units (mg/kg OC). Sediment samples with TOC concentrations <0.5 or >4.0% were not OC-normalized; instead, their dry weight results were compared to the dry weight apparent effects thresholds (AET) (Barrick et al. 1988) criteria. The lowest apparent effects threshold (LAET) and second lowest apparent effects threshold (2LAET) criteria are analogous to SMS sediment quality standards (SQS) and cleanup screening levels (CSL), respectively.

Chemical concentrations for the following four LDW RI risk driver chemicals are also discussed relative to the 95% upper confidence limit on the mean of natural background concentrations (AECOM 2010): arsenic (7 mg/kg DW), cPAHs (9 µg toxic equivalency [TEQ]/kg DW), total PCBs (2 µg/kg DW), and dioxins/furans (2 ng TEQ/kg DW). Individual sample results compared to natural background concentrations are presented in Appendix A, Table A–5.

3.2.1 Metals

Table 3–2 summarizes the metals results for the surface sediment samples, including the number and percentage of detections for each metal, the range and mean of detected concentrations, and the range of reporting limits (RLs) for nondetect results. SMS criteria are presented in Table 3–2 for comparison purposes. Samples from all 162 sampling locations were analyzed for metals, and each metal was detected in at least one sample. Chromium, copper, lead, and zinc were detected in all samples (100%). Arsenic, cadmium, and mercury were detected in the majority of samples analyzed (65% or greater), and silver was detected in only six samples (4%). The highest concentrations of chromium, copper, silver, and zinc were detected in sample LDW-SSSP3-A. The highest concentrations of arsenic and lead were detected in sample LDW-SS5002-A, and the highest concentrations of cadmium and mercury were detected in sample LDW-SS2027-A. Individual sample results are presented in Appendix Table A–1.

Table 3–2. Summary of Metals Results (mg/kg DW)

Chemical	Detection Frequency		Detected Concentrations			Range of RLs of Nondetects
	Ratio	%	Minimum	Maximum	Mean	
Arsenic	152 / 162	94%	6	86	17	6 – 30
Cadmium	105 / 162	65%	0.3	4.0	0.56	0.2 – 0.5
Chromium	162 / 162	100%	10.9 J	160	28	na
Copper	162 / 162	100%	10.6	334 J	50	na
Lead	162 / 162	100%	3 J	166	27	na
Mercury	139 / 162	86%	0.03	6.5	0.16	0.02 – 0.03
Silver	6 / 162	4%	0.4	0.8	0.72	0.3 – 2
Zinc	162 / 162	100%	31	1440 J	130	na

DW = dry weight; J = estimated concentration; na = not applicable; RL = reporting limit

Table 3–3 presents a summary of sediment metals results compared to SMS criteria, including a count of both detected and nondetected results that are less than the SQS, greater than SQS but less than the CSL, and greater than the CSL. Arsenic was detected in four samples at concentrations greater than the SQS but less than the CSL. Mercury was detected in one sample at a concentration greater than the CSL, and one sample at a concentration greater than the SQS but less than the CSL. Zinc was detected in two samples at concentrations greater than the CSL, and in three samples at concentrations greater than the SQS but less than the CSL. All RLs for nondetect results were below SQS. Figure 3 presents all detected metals with concentrations that exceed SMS criteria.

Table 3–3. Counts of Sediment Sample Results Compared to SMS Criteria for Metals

Chemical	SQS	CSL	Count of Detected Concentrations			Count of Nondetect Results		
	mg/kg DW		≤SQS	>SQS, ≤CSL	>CSL	≤SQS	>SQS, ≤CSL	>CSL
Arsenic	57	93	148	4		10		
Cadmium	5.1	6.7	105			57		
Chromium	260	270	162			0		
Copper	390	390	162			0		
Lead	450	530	162			0		
Mercury	0.41	0.59	137	1	1	23		
Silver	6.1	6.1	6			156		
Zinc	410	960	157	3	2	0		

CSL = Cleanup Screening Level; DW = dry weight; SMS = Washington State Sediment Management Standards; SQS = Sediment Quality Standard

Arsenic was detected at 152 of 162 sampling locations, and 143 of these detected concentrations exceeded the natural background concentration of arsenic in sediment, 7 mg/kg DW (AECOM 2010). Three RLs for nondetect arsenic results exceeded the natural background concentration, ranging from 8 to 30 mg/kg DW. Individual sample results compared to the natural background concentration for arsenic in sediment are presented in Appendix A, Table A–5.

3.2.2 SVOCs

Table 3–4 summarizes SVOC sediment results in samples collected from 162 locations, including the number and percentage of detections for each chemical, the range and mean of detected concentrations, and the range of RLs for nondetect results. Results in Table 3–4 are presented in dry weight units as reported by ARI.

Carcinogenic PAH values were calculated using potency equivalency factor (PEF) values (Cal/EPA 1994) based on an individual compound's relative toxicity to benzo(a)pyrene. Final cPAH concentrations are equivalent to the sum of the concentrations of the seven individual cPAH compounds multiplied by their associated PEF. Nondetected values were assessed as half of the reporting limit.

All individual PAH compounds were detected in at least one sediment sample. Fifteen individual PAHs were detected in more than half of the samples (51% or greater), including acenaphthene, anthracene, benzo(a)anthracene, total benzofluoranthenes, benzo(g,h,i)perylene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, dibenzofuran, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene. Three PAH compounds, acenapthylene, 1-methylnaphthalene, and 2-methylnaphthalene, were detected in 39 or more locations (24 percent or greater).

All of the six individual phthalate compounds were detected. Butyl benzyl phthalate and bis(2-ethylhexyl)phthalate (BEHP) were the most commonly detected phthalate compounds, detected in samples collected from 150 and 112 locations (93 and 69%), respectively.

Phenol and 4-methylphenol were the most commonly detected phenol compounds, detected in samples collected from 130 and 111 locations (80 and 69%), respectively. Benzyl alcohol, benzoic acid, and carbazole were detected in samples collected from 146, 127, and 104 locations (90, 78%, and 64%), respectively.

Table 3–4. Summary of SVOC Results (µg/kg DW)

Chemical	Detection Frequency		Detected Concentrations			Range of RLs of Nondetects
	Ratio	%	Minimum	Maximum	Mean	
PAHs						
Acenaphthene	83 / 162	51%	5.8 J	1,200	69	16 – 20
Acenaphthylene	39 / 162	24%	4.8 J	390	35	16 – 20
Anthracene	119 / 162	73%	5.7 J	4,800	120	16 – 20
Benzo(a)anthracene	144 / 162	89%	12 J	4,800	200	16 – 20
Benzofluoranthene	153 / 162	94%	7.7 J	4,200	320	16 – 19
Benzo(g,h,i)perylene	142 / 162	88%	9.9 J	3,100	110	16 – 20
Benzo(a)pyrene	146 / 162	90%	9.9 J	1,400	140	16 – 19
Chrysene	154 / 162	95%	5.7 J	5,800	270	16 – 19
Dibenzo(a,h)anthracene	134 / 162	83%	3.3 J	560	36	3.9 – 5
Dibenzofuran	83 / 162	51%	4.7 J	590	48	16 – 20
Fluoranthene	157 / 162	97%	7.7 J	18,000	520	16 – 19
Fluorene	96 / 162	59%	6.6 J	2,700	84	16 – 20
Indeno(1,2,3-cd)pyrene	140 / 162	86%	8.7 J	2,100	92	16 – 20
1-Methylnaphthalene	60 / 162	37%	5.6 J	100	20	16 – 20
2-Methylnaphthalene	78 / 162	48%	4.7 J	210	25	16 – 20
Naphthalene	100 / 162	62%	4.8 J	89	26	16 – 20
Phenanthrene	150 / 162	93%	7.7 J	11,000	310	16 – 20
Pyrene	157 / 162	97%	7.7 J	14,000	450	16 – 19
Total cPAHs	155 / 162	96%	11 J	2,500	200	11 – 13
Total HPAHs	158 / 162	98%	9.6 J	49,000	2,000	16 – 19
Total LPAHs	150 / 162	93%	7.7 J	20,000	530	16 – 20
Phthalates						
Butyl benzyl phthalate	150 / 162	93%	2.7 J	1,600	32	4.5 – 4.9
Dibutyl phthalate	39 / 162	24%	4.8 J	260	32	16 – 20
Di-n-octyl phthalate	13 / 162	8%	7.8 J	740	89	16 – 20
Diethyl phthalate	26 / 162	16%	4.8 J	81	18	16 – 51

Table 3–4. Summary of SVOC Results (µg/kg DW) (continued)

Chemical	Detection Frequency		Detected Concentrations			Range of RLs of Nondetects
	Ratio	%	Minimum	Maximum	Mean	
Dimethyl phthalate	56 / 162	35%	2.5 J	970	47	3.9 – 5
Bis(2-ethylhexyl)phthalate	112 / 162	69%	9.3 J	37,000	570	10 – 300
Phenols						
2,4,5-Trichlorophenol	0 / 162	0%	na	na	na	77 – 100
2,4,6-Trichlorophenol	1 / 162	1%	17 J	17 J	17	77 – 100
2,4-Dichlorophenol	1 / 162	1%	13 J	13 J	13	77 – 100
2,4-Dimethylphenol	43 / 161	27%	2.4 J	37 J	5.8	3.9 – 5
2,4-Dinitrophenol	0 / 139	0%	na	na	na	160 – 210
2-Chlorophenol	0 / 162	0%	na	na	na	16 – 20
2-Nitrophenol	0 / 162	0%	na	na	na	77 – 100
4,6-Dinitro-2-Methylphenol	0 / 160	0%	na	na	na	160 – 200
4-Chloro-3-Methylphenol	0 / 162	0%	na	na	na	77 – 100
2-Methylphenol	30 / 162	19%	2.8 J	20	5.9	3.9 – 5
4-Methylphenol	111 / 162	69%	4.6 J	4,900	140	16 – 20
4-Nitrophenol	0 / 162	0%	na	na	na	77 – 100
Pentachlorophenol	29 / 162	18%	5.3 J	94 J	22	19 – 25
Phenol	130 / 162	80%	6.7 J	480	52	16 – 20
Other SVOCs (µg/kg DW)						
Benzoic Acid	127 / 162	78%	29 J	1,200	260	160 – 200
Benzyl Alcohol	146 / 162	90%	2.5 J	650	160	4 – 18
4-Bromophenyl phenyl ether	1 / 162	1%	13 J	13 J	13	16 – 20
Carbazole	104 / 162	64%	5.6 J	950	53	16 – 20
Bis(2-chloro-1-methylethyl) ether	0 / 162	0%	na	na	na	16 – 20
4-Chloroaniline	0 / 155	0%	na	na	na	77 – 100
2-Chloronaphthalene	1 / 162	1%	20	20	20	16 – 20
bis(2-Chloroethoxy)Methane	0 / 162	0%	na	na	na	16 – 20
bis(2-Chloroethyl)Ether	1 / 162	1%	30	30	30	16 – 20
4-Chlorophenyl-phenylether	1 / 162	1%	18 J	18 J	18	16 – 20
1,2-Dichlorobenzene	3 / 162	2%	3.8 J	29	13	3.9 – 5
1,3-Dichlorobenzene	1 / 162	1%	240	240	240	16 – 20
1,4-Dichlorobenzene	12 / 162	7%	2.5 J	150	23	3.9 – 5
3,3'-Dichlorobenzidine	0 / 152	0%	na	na	na	77 – 100
2,4-Dinitrotoluene	0 / 162	0%	na	na	na	77 – 100
2,6-Dinitrotoluene	0 / 162	0%	na	na	na	77 – 100
Hexachlorobenzene	5 / 162	3%	1.0 J	29	15	3.9 – 5
Hexachlorobutadiene	1 / 162	1%	3.2 J	3.2 J	3.2	3.9 – 5
Hexachlorocyclopentadiene	0 / 153	0%	na	na	na	77 – 100
Hexachloroethane	0 / 162	0%	na	na	na	16 – 20
Isophorone	0 / 162	0%	na	na	na	16 – 20

Table 3–4. Summary of SVOC Results (µg/kg DW) (continued)

Chemical	Detection Frequency		Detected Concentrations			Range of RLs of Nondetects
	Ratio	%	Minimum	Maximum	Mean	
2-Nitroaniline	0 / 162	0%	na	na	na	77 – 100
3-Nitroaniline	1 / 158	1%	540	540	540	77 – 100
4-Nitroaniline	0 / 159	0%	na	na	na	77 – 100
Nitrobenzene	0 / 162	0%	na	na	na	16 – 20
N-Nitrosodiphenylamine	12 / 162	7%	2.6 J	19	8.5	3.9 – 5
N-Nitrosodi-n-propylamine	2 / 162	1%	29 J	57	43	3.9 – 5
1,2,4-Trichlorobenzene	3 / 162	2%	6.1	15 J	9.4	3.9 – 5
Aniline	2 / 152	1%	15 J	23 J	19	100 – 130
N-Nitrosodimethylamine	2 / 162	1%	3.1 J	5.6 J	4.4	19 – 25

cPAHs = carcinogenic polycyclic aromatic hydrocarbons; DW = dry weight; HPAHs = high molecular weight polycyclic aromatic hydrocarbons; J = estimated concentration; LPAHs = low molecular weight polycyclic aromatic hydrocarbons; na = not applicable; PAHs = polycyclic aromatic hydrocarbons; RL = reporting limit; SVOCs = semi-volatile organic compounds

Table 3–5 summarizes OC-normalized SVOC results for 147 samples with TOC concentrations ≥0.5 and ≤ 4.0%. Only chemicals with OC-normalized SMS criteria are presented in Table 3–5. Each of these chemicals was detected in at least one sediment sample.

Table 3–5. Summary of SVOC Results for Chemicals with OC-normalized SMS criteria (mg/kg OC)

Chemical	Detection Frequency		Detected Concentrations			RL or Range of RLs of Nondetects
	Ratio	%	Minimum	Maximum	Mean	
PAHs						
Acenaphthene	78 / 147	53%	0.19 J	58	3.3	0.50 – 3.7
Acenaphthylene	35 / 147	24%	0.30 J	5.8	1.2	0.50 – 3.7
Anthracene	112 / 147	76%	0.31 J	230	5.8	0.57 – 3.7
Benzo(a)anthracene	134 / 147	91%	0.56 J	230	9.9	0.74 – 3.4
Benzofluoranthene	142 / 147	97%	0.41 J	200	16	1.5 – 2.9
Benzo(g,h,i)perylene	133 / 147	90%	0.47 J	22	4.2	1.0 – 3.7
Benzo(a)pyrene	136 / 147	93%	0.47 J	67	6.5	1.0 – 2.9
Chrysene	142 / 147	97%	0.31 J	280	14	1.5 – 2.9
Dibenzo(a,h)anthracene	125 / 147	85%	0.14 J	9.6	1.6	0.19 – 0.94
Dibenzofuran	77 / 147	52%	0.14 J	25	2.2	0.57 – 3.7
Fluoranthene	146 / 147	99%	0.52 J	870	26	2.9
Fluorene	89 / 147	61%	0.19 J	130	4.1	0.57 – 3.7
Indeno(1,2,3-cd)pyrene	131 / 147	89%	0.43 J	22	3.8	0.91 – 3.7
2-Methylnaphthalene	74 / 147	50%	0.14 J	7.1	1.2	0.50 – 3.7
Naphthalene	94 / 147	64%	0.19 J	7.4	1.3	0.57 – 3.7
Phenanthrene	138 / 147	94%	0.41 J	530	15	1.2 – 2.9

Table 3–5. Summary of SVOC Results for Chemicals with OC-normalized SMS criteria (mg/kg OC) (continued)

Chemical	Detection Frequency		Detected Concentrations			RL or Range of RLs of Nondetects
	Ratio	%	Minimum	Maximum	Mean	
Pyrene	146 / 147	99%	0.52 J	670	22	2.9
Total HPAHs	146 / 147	99%	1.8 J	2,400	100	2.9
Total LPAHs	138 / 147	94%	0.41 J	960	26	1.2 – 2.9
Phthalates						
Butyl benzyl phthalate	140 / 147	95%	0.12 J	53	1.4	0.22 – 0.72
Dibutyl phthalate	34 / 147	23%	0.16 J	8.7	1.7	0.50 – 3.7
Di-n-octyl phthalate	11 / 147	7%	0.31 J	25	4.1	0.50 – 3.7
Diethyl phthalate	21 / 147	14%	0.26 J	6.5	1.1	0.50 – 3.7
Dimethyl phthalate	49 / 147	33%	0.076 J	24	1.2	0.13 – 0.94
Bis(2-ethylhexyl)phthalate	101 / 147	69%	1.0	1,200	25	0.79 – 21
Other SVOCs						
1,2-Dichlorobenzene	3 / 147	2%	0.15 J	0.97	0.55	0.13 – 0.94
1,4-Dichlorobenzene	12 / 147	8%	0.082 J	6.6	1.1	0.13 – 0.94
Hexachlorobenzene	3 / 147	2%	0.32	1.2	0.68	0.13 – 0.94
Hexachlorobutadiene	1 / 147	1%	0.13 J	0.13 J	0.13	0.13 – 0.94
N-Nitrosodiphenylamine	9 / 147	6%	0.15 J	1.3 J	0.46	0.13 – 0.94
1,2,4-Trichlorobenzene	2 / 147	1%	0.31	0.60 J	0.46	0.13 – 0.94

HPAHs = high molecular weight polycyclic aromatic hydrocarbons; J = estimated concentration; LPAHs = low molecular weight polycyclic aromatic hydrocarbons; PAHs = polycyclic aromatic hydrocarbons; RL = reporting limit; SVOCs = semi-volatile organic compounds

Table 3–6 presents a summary of the number of sediment results for SVOC compounds compared to SMS criteria, including a count of detected and nondetected results that are less than the SQS/LAET, greater than SQS/LAET but less than the CSL/2LAET, and greater than the CSL/2LAET. Thirteen SVOCs were detected at concentrations greater than the CSL/2LAET including the following: benzyl alcohol (94 samples); benzoic acid (5 samples); BEHP (3 samples); and acenaphthene, benzo(g,h,i)perylene, dibenzo(a,h)anthracene, fluorene, indeno(1,2,3-cd)pyrene, phenanthrene, total low molecular weight polycyclic aromatic hydrocarbons (LPAHs), 2,4-dimethylphenol, 4-methylphenol, and dimethyl phthalate (1 sample each).

Fifteen SVOCs were detected at concentrations greater than the SQS/LAET but less than the CSL/2LAET including the following: benzyl alcohol (7 samples); butyl benzyl phthalate (6 samples); hexachlorobenzene, dibenzofuran, and BEHP (3 samples each); 1,4-dichlorobenzene, acenaphthene, fluoranthene, phenanthrene, and total high molecular weight polycyclic aromatic hydrocarbons (HPAHs) (2 samples each); and anthracene, benzo(a)anthracene, chrysene, fluorene, and phenol (1 sample each). All RLs for nondetect results were below SQS, except for hexachlorobenzene in 23 samples and 1,2,4-trichlorobenzene in 2 samples. Figure 3 presents all detected SVOCs with concentrations that exceed SMS criteria.

Table 3–6. Counts of Sediment Sample Results Compared to SMS Criteria for SVOCs

Chemical	SQS	CSL	LAET	2LAET	Count of Detected Concentrations			Count of Nondetected Results		
	mg/kg OC		µg/kg DW		≤SQS/ LAET	>SQS/LAET, ≤CSL/2LAET	>CSL/ 2LAET	≤SQS/ LAET	>SQS/LAET, ≤CSL/2LAET	>CSL/ 2LAET
PAHs										
Acenaphthene	16	57	500	730	80	2	1	79		
Acenaphthylene	66	66	1,300	1,300	39			123		
Anthracene	220	1,200	960	4,400	118	1		43		
Benzo(a)anthracene	110	270	1,300	1,600	143	1		18		
Benzofluoranthene	230	450	3,200	3,600	153			9		
Benzo(g,h,i)perylene	31	78	670	720	141		1	20		
Benzo(a)pyrene	99	210	1,600	3,000	146			16		
Chrysene	110	460	1,400	2,800	153	1		8		
Dibenzo(a,h)anthracene	12	33	230	540	133		1	28		
Dibenzofuran	15	58	540	700	80	3		79		
Fluoranthene	160	1,200	1,700	2,500	155	2		5		
Fluorene	23	79	540	1,000	94	1	1	66		
Indeno(1,2,3-cd)pyrene	34	88	600	690	139		1	22		
2-Methylnaphthalene	38	64	670	1,400	78			84		
Naphthalene	99	170	2,100	2,400	100			62		
Phenanthrene	100	480	1,500	5,400	147	2	1	12		
Pyrene	1,000	1,400	2,600	3,300	157			5		
Total HPAHs	960	5,300	12,000	17,000	156	2		4		
Total LPAHs	370	780	5,200	13,000	149		1	12		
Phenols										
2,4-Dimethylphenol	29 [a]	29 [a]	na	na	42		1	118		
2-Methylphenol	63 [a]	63 [a]	na	na	30			132		
4-Methylphenol	670 [a]	670 [a]	na	na	110		1	51		
Pentachlorophenol	360 [a]	690 [a]	na	na	29			133		
Phenol	420 [a]	1,200 [a]	na	na	129	1		32		

Table 3–6. Counts of Sediment Sample Results Compared to SMS Criteria for SVOCs (continued)

Chemical	SQS	CSL	LAET	2LAET	Count of Detected Concentrations			Count of Nondetected Results		
	mg/kg OC		µg/kg DW		≤SQS/ LAET	>SQS/LAET, ≤CSL/2LAET	>CSL/ 2LAET	≤SQS/ LAET	>SQS/LAET, ≤CSL/2LAET	>CSL/ 2LAET
Phthalates										
Butyl benzyl phthalate	4.9	64	63	900	144	6		12		
Dibutyl phthalate	220	1,700	1,400	5,100	39			123		
Di-n-octyl phthalate	58	4,500	6,200	-	13			149		
Diethyl phthalate	61	110	200	1,200	26			136		
Dimethyl phthalate	53	53	71	160	55		1	106		
Bis(2-ethylhexyl)phthalate	47	78	1,300	1,900	106	3	3	50		
Other SVOCs										
Benzoic Acid	650 [a]	650 [a]	na	na	122		5	35		
Benzyl Alcohol	57 [a]	73 [a]	na	na	45	7	94	16		
1,2-Dichlorobenzene	2.3	2.3	35	50	3			159		
1,4-Dichlorobenzene	3.1	9	110	120	10	2		150		
Hexachlorobenzene	0.38	2.3	22	70	2	3		134	23	
Hexachlorobutadiene	3.9	6.2	11	120	1			161		
N-Nitrosodiphenylamine	11	11	28	40	12			150		
1,2,4-Trichlorobenzene	0.81	1.8	31	51	3			157	2	

[a] These criteria are in units of µg/kg DW (not mg/kg OC).

2LAET = second lowest apparent effects threshold; CSL = cleanup screening level; DW = dry weight; HPAHs = high molecular weight polycyclic aromatic hydrocarbons; LAET = lowest apparent effects threshold; LPAHs = low molecular weight polycyclic aromatic hydrocarbons; na = not applicable; OC = organic carbon normalized; PAHs = polycyclic aromatic hydrocarbons; SVOCs = semi-volatile organic compounds; SMS = sediment management standards; SQS = sediment quality standards

Carcinogenic PAHs were detected in samples collected at 155 of the 162 sampling locations. All detected results exceeded the natural background concentration of cPAHs in sediment, 9 µg TEQ/kg DW (AECOM 2010). All seven RLs for nondetect cPAH results exceeded the natural background concentration, ranging from 11 to 13 µg TEQ/kg DW. Individual sample results compared to the natural background concentration for cPAHs in sediment are presented in Appendix A, Table A–5. Sample results for cPAHs are also presented in Figure 3.

3.2.3 PCBs

Total PCBs were detected in all samples. Aroclor 1242, Aroclor 1248, Aroclor 1254, and Aroclor 1260 were detected in one or more sample. Results for the individual Aroclors and total PCBs are summarized in Table 3–7.

Table 3–7. Summary of PCB Aroclor Results (µg/kg DW)

Chemical	Detection Frequency		Detected Concentrations			Range of RLs of Nondetects
	Ratio	%	Minimum	Maximum	Mean	
Aroclor 1016	0 / 162	0%	na	na	na	3.7 - 79
Aroclor 1221	0 / 162	0%	na	na	na	3.7 - 79
Aroclor 1232	0 / 162	0%	na	na	na	3.7 - 79
Aroclor 1242	2 / 162	1%	10 J	15	13	3.7 - 79
Aroclor 1248	99 / 162	61%	3.7 J	330	33	3.8 - 130
Aroclor 1254	147 / 162	91%	4.0	370	42	3.7 - 200
Aroclor 1260	138 / 162	85%	3 J	1200	45	3.7 - 14
Total PCBs	154 / 162	95%	4.4	1200	100	3.9 - 7.8
Total PCBs (mg/kg OC)	142 / 147	97%	0.24	78	5.6	0.12 - 0.47

DW = dry weight; na = not applicable; OC = organic carbon normalized; PCB = polychlorinated biphenyl; RLs = reporting limits

Table 3–8 presents a summary of the number of total PCBs results for sediment samples compared to SMS criteria, including a count of detected and nondetected results that are less than the SQS/LAET, greater than SQS/LAET but less than the CSL/2LAET, and greater than the CSL/2LAET. Total PCBs were detected in one sample at a concentration exceeding the CSL, sample LDW-SS5003-A. Ten samples had detected concentrations of total PCBs greater than the SQS/LAET but less than the CSL/2LAET. All RLs for nondetect results were below SQS. Figure 3 presents the locations with detected concentrations of total PCBs that exceed SMS criteria.

Table 3–8. Counts of Sediment Sample Results Compared to SMS Criteria for Total PCBs

Chemical	SQS	CSL	LAET	2LAET	Count of Detected Concentrations			Count of Nondetected Results		
	mg/kg OC		µg/kg DW		≤SQS/ LAET	>SQS/LAET, ≤CSL/2LAET	>CSL/2 LAET	≤SQS/ LAET	>SQS/LAET, ≤CSL/2LAET	>CSL/ 2LAET
Total PCBs	12	65	130	1,000	143	10	1	8		

2LAET = second lowest apparent effects threshold; CSL = cleanup screening level; DW = dry weight; LAET = lowest apparent effects threshold; OC = organic carbon normalized; PCB = polychlorinated biphenyl; SMS = sediment management standards; SQS = sediment quality standards

Total PCBs were detected in samples collected at 154 of the 162 sampling locations. All detected results exceeded the natural background concentration of total PCBs in sediment, 2 µg/kg DW (AECOM 2010). The eight RLs for nondetect total PCB results also exceeded the natural background concentration, ranging from 3.9 to 7.8 µg/kg DW. Individual sample results compared to the natural background concentration for total PCBs in sediment are presented in Appendix A, Table A–5.

3.2.4 Dioxins/Furans

Sediment samples collected from 30 sampling locations were analyzed for dioxins/furans. The TEQ concentration of the dioxin/furan congeners were normalized to the toxicity of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) using toxicity equivalency factors (TEFs) updated by the World Health Organization in 2005 (Van den Berg et al. 2006) and incorporated into the MTCA (Ecology 2007, WAC 173-340). The TEQ is equivalent to the sum of the concentrations of individual congeners multiplied by their TEF (toxicity relative to 2,3,7,8-TCDD). Nondetected values were assessed as half the sample specific detection limit for nondetected congeners.

Dioxin/furan results are summarized in Table 3–9. All of the individual 17 dioxin/furan congeners were detected in one or more sediment samples. Dioxin/furan TEQs ranged from 0.294 to 23.4 ng TEQ/kg DW, with an average of 4.66 ng TEQ/kg DW. Sample LDW-SS5000-A had the highest dioxin/furan TEQ concentration (23.4 ng TEQ/kg DW) and sample LDW-SS2013-A had the second highest dioxin/furan TEQ concentration (9.01 ng TEQ/kg DW).

Dioxins/furans were analyzed in samples collected from 30 sampling locations. All of these samples had detected concentrations of at least one dioxin/furan congener. Nineteen results exceeded the natural background concentration of dioxins/furans in sediment, 2 ng TEQ/kg DW (AECOM 2010). Individual sample results compared to the natural background concentration for cPAHs in sediment are presented in Appendix A, Table A–5. Dioxin/furan TEQ sample concentrations are presented in Figure 3.

Table 3–9. Summary of Dioxin/Furan Results (ng TEQ/kg DW)

Chemical	Detection Frequency		Detected Concentrations			RL or Range of RLs of Nondetects
	Ratio	%	Minimum	Maximum	Mean	
2,3,7,8-TCDD	11 / 30	37%	0.0860 J	0.440 J	0.345	0.058 – 0.449
1,2,3,7,8-PeCDD	27 / 30	90%	0.0680 J	1.87 J	0.730	0.085 – 1.01
1,2,3,4,7,8-HxCDD	27 / 30	90%	0.178 J	4.04 J	1.38	0.118 – 0.556
1,2,3,6,7,8-HxCDD	30 / 30	100%	0.396 J	20.8	5.06	na
1,2,3,7,8,9-HxCDD	29 / 30	97%	0.357 J	10.4 J	3.81	0.329
1,2,3,4,6,7,8-HpCDD	30 / 30	100%	7.68	578	126	na
OCDD	30 / 30	100%	59.6	5580	1150	na
2,3,7,8-TCDF	23 / 30	77%	0.144 J	1.18	0.527	0.0489 – 0.372
1,2,3,7,8-PeCDF	18 / 30	60%	0.110 J	1.76 J	0.483	0.0461 – 0.543
2,3,4,7,8-PeCDF	28 / 30	93%	0.102 J	4.94	0.841	0.066 – 0.097
1,2,3,4,7,8-HxCDF	30 / 30	100%	0.136 J	55.6	4.02	na
1,2,3,6,7,8-HxCDF	28 / 30	93%	0.102 J	9.36	1.18	0.065 – 0.107
1,2,3,7,8,9-HxCDF	9 / 30	30%	0.0820 J	0.689 J	0.177	0.0461 – 0.132
2,3,4,6,7,8-HxCDF	28 / 30	93%	0.0820 J	4.60 J	0.842	0.08 – 0.607
1,2,3,4,6,7,8-HpCDF	29 / 30	97%	1.32 J	210	25.3	4.66
1,2,3,4,7,8,9-HpCDF	28 / 30	93%	0.126 J	28.4	2.43	0.132 – 2.15
OCDF	29 / 30	97%	2.69 J	689	80.2	11.5
Dioxin/Furan TEQ	30 / 30	100%	0.294 J	23.4 J	4.66	na

Table 3–9. Summary of Dioxin/Furan Results (ng TEQ/kg DW) (continued)

Chemical	Detection Frequency		Detected Concentrations			RL or Range of RLs of Nondetects
	Ratio	%	Minimum	Maximum	Mean	
Total TCDD	30 / 30	100%	0.054	7.00	3.01	na
Total TCDF	30 / 30	100%	0.646	24.2	10.9	na
Total PeCDD	30 / 30	100%	0.282	11.6	5.43	na
Total PeCDF	30 / 30	100%	0.908	62.6	13.2	na
Total HxCDD	30 / 30	100%	2.51	111	42.1	na
Total HxCDF	30 / 30	100%	1.87	369	38.8	na
Total HpCDD	30 / 30	100%	16.7	1260	357	na
Total HpCDF	30 / 30	100%	3.45	891	89.5	na

DW = dry weight; HpCDD = heptachlorodibenzo-*p*-dioxin; HpCDF = heptachlorodibenzofuran; HxCDD = hexachlorodibenzo-*p*-dioxin; HxCDF = hexachlorodibenzofuran; na = not applicable; RL = reporting limit; OCDD = octachlorodibenzo-*p*-dioxin; OCDF = octachlorodibenzofuran; PeCDD = pentachlorodibenzo-*p*-dioxin; PeCDF = pentachlorodibenzofuran; TCDD = tetrachlorodibenzo-*p*-dioxin; TCDF = tetrachlorodibenzofuran; TEQ = toxic equivalency

3.2.5 Grain Size and Conventionals

Grains size, TOC, and total solids results are summarized in Table 3–10. Total fines ranged from 0.1 to 94.5 percent. TOC concentrations ranged from 0.156 to 11.7 percent with an average of 2.11 percent. Totals solids ranged from 34.4 to 85.8 percent with an average of 56.0 percent.

There was insufficient sample volume to perform the hydrometer portion of the grain size analysis for samples collected from the following locations: LDW-SS2040-A, LDW-SS2040-D, LDW-SS2040-U, LDW-SS2150-A, LDW-SS2232-D, LDW-SS2233-D, LDW-SS2233-U, LDW-SS2505-A, LDW-SS2512-A, LDW-SSRWSD-A, LDW-SSRWSD-Ab, LDW-SSSP1-D, LDW-SSSP2-A, LDW-SSSP3-A, and LDW-SSUNK-D. Consequently, all fractions with phi scale greater than 4 were reported as nondetect by the laboratory, and total fines (silt/clay) was reported as detected concentration with a value represented by 100 percent minus the sand and gravel fractions.

Table 3–10. Summary of Grain Size, TOC, and Total Solids Results

Chemical	Detection Frequency		Detected Concentrations			RL or Range of RLs of Nondetects
	Ratio	%	Minimum	Maximum	Mean	
Grain size (% DW)						
Phi Scale <-1	136 / 162	84%	0.1	77.6	9.90	0.1
Phi Scale -1 to 0	162 / 162	100%	0.2	12.7	3.20	na
Phi Scale 0 to 1	162 / 162	100%	0.8	64.5	7.31	na
Phi Scale 1 to 2	162 / 162	100%	0.4	70.9	13.7	na
Phi Scale 2 to 3	162 / 162	100%	0.6	31.5	8.75	na
Phi Scale 3 to 4	161 / 162	99%	0.4	30.2	9.89	0.1
Phi Scale 4 to 5	147 / 162	91%	0.1	28.2	10.2	0.1 - 5.7
Phi Scale 5 to 6	147 / 162	91%	0.9	29.2	12.2	0.1 - 5.7

Table 3–10. Summary of Grain Size, TOC, and Total Solids Results (continued)

Chemical	Detection Frequency		Detected Concentrations			RL or Range of RLs of Nondetects
	Ratio	%	Minimum	Maximum	Mean	
Phi Scale 6 to 7	147 / 162	91%	0.7	28.1	11.4	0.1 - 5.7
Phi Scale 7 to 8	147 / 162	91%	0.4	17.7	7.59	0.1 - 5.7
Phi Scale 8 to 9	147 / 162	91%	0.3	11.4	4.43	0.1 - 5.7
Phi Scale 9 to 10	147 / 162	91%	0.1	7.7	2.8	0.1 - 5.7
Phi Scale >10	147 / 162	91%	0.4	13.4	4.98	0.1 - 5.7
Total Clay (<0.004 mm - 0.004 mm)	147 / 162	91%	1.0	31.3	12.2	0.1 - 5.7
Total Silt (0.06 mm - 0.004 mm)	147 / 162	91%	3.1	76.3	41.4	0.1 - 5.7
Total Fines (Silt/Clay)	162 / 162	100%	0.1	94.5	48.9	na
Total Sand (<2.0 mm - 0.06 mm)	162 / 162	100%	5.3	98.3	42.8	na
Total Gravel (>2.0 mm)	136 / 162	84%	0.1	77.6	9.90	0.1
Conventionals						
TOC (% DW)	162 / 162	100%	0.156	11.7	2.11	na
Total Solids (% WW)	162 / 162	100%	34.4	85.8	56.0	na

TOC = total organic carbon; na = not applicable; DW = dry weight; RL = reporting limit; WW = wet weight

3.3 Quality Assurance/Quality Control

Analyses were conducted following the QA/QC requirements specified in the project SAP/QAPP (SAIC 2011). The QA/QC procedures ensure that the results of the investigation are defensible and usable for their intended purpose.

3.3.1 Field Duplicate Samples

Field duplicate samples were collected at a rate of one per 20 normal samples collected for analysis. Field duplicate samples were collected at the same time and analyzed for the same chemicals as the original sample. Field duplicate sample results are used to assess the precision of the sample collection process and to help determine the representativeness of the sample. The results of the field duplicate samples are discussed in the data validation report in Appendix B.

3.3.2 Rinse Blanks

One rinse blank sample was collected during each week of sample collection to measure the effectiveness of the decontamination procedures of the sampling equipment. The rinse blank samples consist of reagent grade water provided by ARI rinsed across sample collection and processing equipment. Rinse blank samples were analyzed for SVOCs, PCBs, and metals. If chemicals were detected in the rinse blank samples, the detected concentrations were compared to the associated sample results to evaluate the potential for cross contamination. The rinse blank results are discussed in the data validation report, presented in Appendix B.

3.3.3 Data Validation

All chemical results gathered during this investigation were independently validated by EcoChem, Inc. of Seattle, WA. A summary-level, EPA Stage 2B data validation was performed on all standard SMS sediment chemistry results; a full-level, EPA Stage 4 data validation was performed on the dioxin/furan results. A compliance-level screening, including a comparison of detected results to sample concentrations, was performed on the rinse blank samples. Data validation was performed following EPA guidance (EPA 1994, 2008, 2009, 2010). The results of the data validation are summarized below. Additional details, including a list of all qualified results, are presented in Appendix B.

Seventy-one results for nine SVOCs were rejected during data validation because of extremely low laboratory control sample/laboratory control sample duplicate (LCS/LCSD) and/or matrix spike/matrix spike duplicate (MS/MSD) percent recoveries (less than 10 percent). Rejected results include 25 results for 2,4-dinitrophenol; 10 results each for aniline and 3,3'-dichlorobenzidine; nine results for hexachlorocyclopentadiene; seven results for 4-chloroaniline; four results for 3-nitroaniline; two results for 4,6-dinitro-2-methylphenol; and one result for 2,4-dimethylphenol. Rejected results should not be used for any purpose. All other results were considered acceptable, as qualified. Issues resulting in data qualification are summarized below.

Results for 52 various chemicals were J- or UJ-qualified as estimated because calibration, calibration verification, MS/MSD, LCS/LCSD, standard reference material, internal standard, and/or surrogate recoveries or duplicate relative percent differences were outside of control limits. Lock mass interferences resulted in J-qualification of two dioxin/furan results, and eight results for four SVOC compounds were J-qualified because of low spectral match. A full list of qualified results including the reason for data qualification is presented in the data validation report.

Thirty-nine results for five chemicals were re-qualified as nondetect at elevated RLs because of method blank contamination, including the following results: 25 results for BEHP ranging from 18 to 300 µg/kg DW, 10 results for benzyl alcohol ranging from 5.8 to 14 µg/kg DW, 2 results for diethyl phthalate ranging from 50 to 51 µg/kg DW, and one result each for OCDF and 1,2,3,4,6,7,8-HPCDF at 11.5 and 4.66 ng/kg DW, respectively. Twenty-five additional BEHP results ranging from 19 to 160 µg/kg DW were re-qualified as nondetect because of rinse blank contamination.

Forty-six results for four individual PCB Aroclors were Y-qualified by ARI as nondetect at elevated RLs because chromatographic interferences prevented adequate resolution of the compound at the standard RL.

Sixty-four results for 11 dioxin/furan congeners were K-qualified by Axys as being estimated maximum possible concentrations because not all method required compound identification parameters were met. These results were requalified as nondetect (U-qualified) at the reported concentrations.

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4.0 References

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